Unsaturated Hydraulic Properties of Gravels

Tetsu K. Tokunaga, Keith R. Olson, and Jiamin Wan
Contact: Tetsu Tokunaga, 510/486-7176, tktokunaga@lbl.gov

RESEARCH OBJECTIVES

Gravels can make up large fractions of the subsurface, including vadose zones. The extensiveness of some gravel deposits is evident from the fact that they serve as major aquifers that supply groundwater for agricultural, industrial, and municipal use. Because some gravel deposits do occur in the vadose zone, understanding unsaturated flow and transport in such settings requires knowledge of their hydraulic properties. Some gravel deposits occur in heavily contaminated vadose zones such as the Hanford Site in Washington State, where radioactive wastes have leaked. Gravels are also an important component in engineered capillary barriers for subsurface waste isolation. However, relatively little information is available on the unsaturated hydraulic properties of gravels. In a recent study (Tokunaga et al., 2002), the levels of residual saturation in Hanford gravels were found to be high, in the range of 0.1 to 0.2. The present work addresses a much broader range of matric (capillary) potentials and saturations in Hanford gravels, and includes characterization of intragranular porosity and water film thicknesses on external grain surfaces.

APPROACH

To cover a wide range of matric potentials (0 to -300 MPa), water-retention measurements were made using suction plate, pressure plate, and vapor-pressure methods (Figure 1). Average water film thicknesses on external surfaces of gravel grains were obtained with a synchrotron x-ray microprobe-based suction plate technique (Tokunaga et al., 2003). External grain surfaces were also characterized with a laser profilometer, atomic force microscope, and scanning electron microscope. Intragranular surface area was determined with adsorption isotherms (water vapor and krypton gas).

ACCOMPLISHMENTS

External surfaces of these gravels have root mean-square roughnesses in the μm range, with sparsely distributed deep (hundreds of μm) pits. Water films on these external surfaces are volumetrically insignificant at matric potentials less than about -2 kPa. Residual water in these gravels occurs in intragranular pores, accounts for about 10% of the total porosity, and is effectively hydraulically immobile. The insignificant advective access to this intragranular domain was established from measurements that show less than 2% change in saturation over the matric potential interval of -10 kPa to -10 MPa. The intragranular domain in Hanford gravels also has a large specific surface area of about 11 $m^2\ g^{-1}$.

SIGNIFICANCE OF FINDINGS

The high specific surface area and porosity associated with interior regions of Hanford gravel grains largely explain why exchanges of solutes (including contaminants) in these sediments are significant and strongly diffusion-limited.

RELATED PUBLICATIONS

Tokunaga, T.K., J. Wan, and K.R. Olson, Saturation-matric potential relations in gravel. Water Resour. Res. 38(10), 1214, doi:10.1029/2001WR001242, 2002.

Tokunaga, T.K., K.R. Olson, and J. Wan, Moisture characteristics of Hanford gravels: Bulk, grain-surface, and intragranular components. Vadose Zone J. accepted June 2, 2003.

ACKNOWLEDGMENTS

This project is supported by the Assistant Secretary of the Office of Environmental Management, Office of Science and Technology, of the U.S. Department of Energy under Contract No. DE-AC03-76-SF00098.

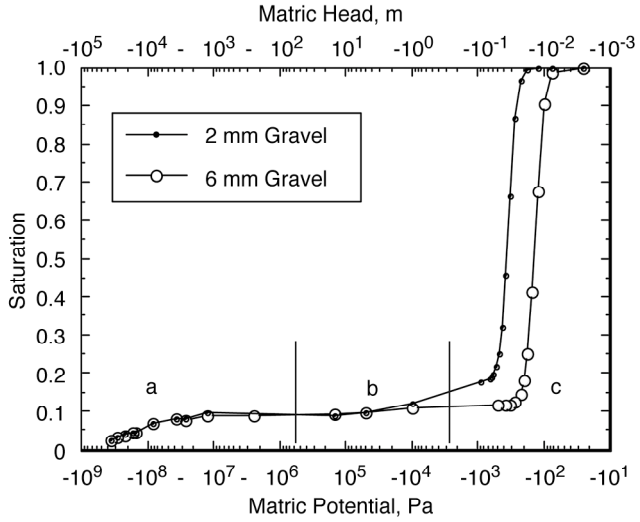

Figure 1. Moisture retention in 2 and 6 mm Hanford gravels, over a wide range of matric (water) potentials. Measurement methods used are indicated along the x-axis as (a) vapor-pressure regulation, (b) pressure plate, and (c) suction plate. The vapor-pressure equilibration region data were obtained in adsorption mode. The suction plate and pressure plate data were obtained in drainage mode.